CRWMS/M&O

Calculation Cover Sheet

Complete only applicable items.

1. QA: ~~N~~ L RLH 8/09/99

Page: 1 Of: 21

2. Calculation Title
RIP Input Tables From WAPDEG For LA Design Selection: Repository Horizon Elevation - 2-Level AML 50% and Near Maximum

3. Document Identifier (including Revision Number)	4. Total Pages
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10. Remarks
Input thermal hydrologic history files (DTN: LL981109004242.064, LL981109104242.065).
Computer software (WAPDEG version 3.09 and Post308) tracked by TBV-568.

Uses DTN: MO9807MWDWAPDG.000 on conceptual model.
Uses DTN: MO9810SPA00013.000 on input assumptions and input data.
Supporting Electronic Media = ACC: MOL.19990615.0040, DTN: MO9906MWDWAP61.001.

For LA Design Selection.

Any obliterated information does not impact the technical meaning or content of this record.

Revision History

11. Revision No.	12. Date Approved	13. Description of Revision
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1.0 Purpose

The purpose of this calculation is to document the WAPDEG version 3.09 (CRWMS M&O 1998b. *Software Routine Report for WAPDEG (Version 3.09)*) simulations used to analyze waste package degradation and failure under the repository exposure conditions characterized by a two-tier thermal loading repository design. Also documented is the post-processing of these results into tables of waste-package-degradation-time histories suitable for use as input into the Integrated Probabilistic Simulator for Environmental Systems (RIP) version 5.19.01 (Golder Associates 1998) computer program.

Specifically, the WAPDEG simulations discussed in this calculation correspond to waste package emplacement conditions (repository environment and design) as defined in the Total System Performance Assessment - Viability Assessment (CRWMS M&O 1998a. *Total System Performance Assessment-Viability Assessment (TSPA-VA) Analyses Technical Basis Document - Chapter 5, Waste Package Degradation Modeling And Abstraction,* pp. 5-27 to 5-29), with the exception that a two-tier thermal loading design feature as specified in the License Application Design Selection (LADS) study was analyzed. The particular design feature evaluated in this report is a modification of the repository horizon elevation and layout within the Topopah Springs Member of Yucca Mountain. Specifically, the modification consists of adding a second level, 50-m above the base case repository layout. Two options were considered, representing two variations in thermal loading. In Design Feature 25e (designated DF25e), each level has an Areal Mass Loading (AML) of 42.5 MTU/acre (i.e., half the VA base case). In Design Feature 25f (designated DF25f), each level has an AML of 64MTU/acre. As a result of the change in waste package placement relative to the TSPA-VA base-case design, different temperature and relative humidity time histories at the waste package surface are calculated (input to the WAPDEG simulations), and consequently different waste package failure histories (as calculated by WAPDEG) result.

2.0 Method

Temperature and relative humidity (RH) time histories at the waste package surface are calculated elsewhere and provided as input to this WAPDEG simulation. These histories are pre-processed into a form suitable for use as input to the WAPDEG stochastic simulation code (CRWMS M&O 1998b. *Software Routine Report for WAPDEG (Version 3.09)*) through the use of the pre-processor Mkhistory (CRWMS M&O 1998c. *Software Routine Report for Mkhistory (Version 1.00)*).

Based on user-supplied input, the stochastic simulation code WAPDEG is used to generate waste package failure profiles. WAPDEG's inputs include time-varying histories of the temperature and relative humidity at the waste package surface (as discussed above), various temperature and relative humidity thresholds for corrosion initiation, corrosion models, and corrosion model parameter distributions. A waste package may fail either through localized corrosion processes (pitting or crevice corrosion), leading to small pinhole perforations (generically referred to as "pits"), or through general corrosion processes leading to much larger "patch" perforations. More detailed discussions of the WAPDEG conceptual model are given elsewhere (CRWMS M&O 1998a. *Total System Performance Assessment-Viability Assessment (TSPA-VA) Analyses Technical Basis Document -*

Chapter 5, Waste Package Degradation Modeling And Abstraction, pp. 5-27 to 5-29) (DTN: MO9807MWDWAPDG.000). The waste package failure profiles calculated by WAPDEG consist of time-varying measures of the number of pit and patch penetrations on each failed waste package. The WAPDEG post-processor, Post308 (CRWMS M&O 1998b. *Software Routine Report for WAPDEG (Version 3.09)*, Appendix D), abstracts this information, to produce one RIP input table (Golder Associates 1998, pp. 7-22 through 7-25) per WAPDEG simulation. The RIP input table contains:

- The package failure versus time curve for the simulation
- The average number of pit penetrations per failed waste package versus time curve
- The average number of patch penetrations per failed waste package versus time curve.

Post308 has two main objectives, it reformats the WAPDEG output to conform to the RIP multidimensional table format, and decreases the number of points (if necessary) in each of the three curves discussed above to 83, through a process of time averaging.

More detailed discussions of the WAPDEG version 3.09 and Post308 codes appear elsewhere (CRWMS M&O 1998b. *Software Routine Report for WAPDEG (Version 3.09)*).

3.0 Assumptions

No assumptions are made in executing Mkhistory. The limitations on the Mkhistory software routine and on the validity of the resulting output are discussed in detail in Mkhistory's Software Routine Report (CRWMS M&O 1998c. *Software Routine Report for Mkhistory (Version 1.00)*). These limitations have no effect on the results of this calculation.

For the calculations involved in attaining a post processed table for input into RIP there are two steps to consider: 1) Execution of the WAPDEG code and; 2) Post processing of WAPDEG output for creation of tables for input to RIP. There are several assumptions necessary to consider for the WAPDEG simulations. The assumptions used to model waste package degradation in this calculation are identical to those used in the TSPA-VA REV 01 base case calculation (CRWMS M&O 1998d. *Creating Input Tables from WAPDEG for RIP*) (DTN: MO9810SPA00013.000). Although WAPDEG version 3.07 (CRWMS M&O 1998j. *Software Routine Report for WAPDEG (Version 3.07)*) was used in the TSPA-VA base case calculation and WAPDEG version 3.09 is used in the present calculation, the assumptions listed in the TSPA-VA REV 01 base case calculation are correct and applicable to the present calculation. This is due to the fact that the additional features of WAPDEG version 3.09 relative to WAPDEG version 3.07 are not used in this calculation. No additional assumptions pertaining to the use of the WAPDEG code are made as a result of considering the two-tier thermal loading design feature. No additional assumptions pertaining to the use of the Post308 code are made as a result of considering the two-tier thermal loading design feature.

4.0 Use of Computer Software

4.1. Software Approved for QA Work

Mkhistory version 1.00 (CRWMS M&O 1998c. *Software Routine Report for Mkhistory (Version 1.00)*) was used to pre-process the thermal hydrologic time, temperature, and relative humidity "histories" into a format usable by the WAPDEG code. The following information has been obtained from the Software Configuration Secretary (SCS) relative to this software:

Software Name:	Mkhistory
Software Version:	1.00
CSCI Identifier:	30080 V1.00
Document Identifier:	30080–2999, REV 00
Media Identifier:	30080–M04–001, REV 00
Software Change Request:	LSBR 194

This software routine was obtained from the Software Configuration Manager in accordance with appropriate procedures. Mkhistory was executed on a DELL PowerEdge 2200 Workstation equipped with Dual (2) Pentium II 266 MHz processors (CRWMS M&O tags 112371, 112517) in the Windows NT 4.0 operating system. Mkhistory version 1.00 has gone through the complete verification and validation process required by QAP-SI-0 REV 04 for a software routine and is thus a fully qualified software routine approved for use in quality affecting work. Mkhistory was used within the range of values tested and documented within its Software Routine Report (CRWMS M&O 1998c. *Software Routine Report for Mkhistory (Version 1.00)*).

Mkhistory version 1.00 is an appropriate tool for this application, because it is able to read input data and produce output files that can be used as input into WAPDEG.

4.2. Software Routines

The software used to perform the waste package degradation simulations was WAPDEG version 3.09 (CRWMS M&O 1998b. *Software Routine Report for WAPDEG (Version 3.09)*) (TBV-568) and its post processor, Post308 (CRWMS M&O 1998b. *Software Routine Report for WAPDEG (Version 3.09)*, Appendix D) (TBV-568). The following has been obtained from the Software Configuration Secretary (SCS) relative to this software routine:

Software Name:	WAPDEG

Software Version:	3.09
CSCI Identifier:	30048 V3.09
Document Identifier:	30048–2999, REV 02
Media Identifier:	30048–M04–001, REV 02
Software Change Request:	LSBR 177

This software was obtained from the Software Configuration Manager in accordance with appropriate procedures. The WAPDEG simulations were executed on a DELL PowerEdge 2200 Workstation equipped with Dual (2) Pentium II 266 MHz processors (CRWMS M&O tags 112371, 112517) in the Windows NT 4.0 operating system. The post processing was accomplished on a DELL PowerEdge 2200 Workstation equipped with Dual (2) Pentium II 266 MHz processors (CRWMS M&O tags 112371, 112517) in the Windows NT 4.0 operating system.

WAPDEG version 3.09 is an appropriate tool for this application, because it was specifically designed to calculate waste package failure profiles in a manner consistent with the information requirements of the RIP code. Although there has been a Software Routine Report (SRR) prepared for version 3.09 of the WAPDEG code (CRWMS M&O 1998b. *Software Routine Report for WAPDEG (Version 3.09)*), WAPDEG did not go through the complete verification and validation process required by QAP-SI-0 REV 04 when effective, so it is not to be considered qualified and has been designated "to be verified" (TBV-568). WAPDEG version 3.09 was used within the range of values tested and documented in its Software Routine Report (CRWMS M&O 1998b. *Software Routine Report for WAPDEG (Version 3.09)*).

Post308 is an appropriate tool for this application, because it is able to read WAPDEG output files and post-process them to make tables for input into RIP. Although all of the documentation necessary to fully qualify the Post308 code has been included in the WAPDEG version 3.09 SRR (CRWMS M&O 1998b. *Software Routine Report for WAPDEG (Version 3.09)*, Appendix D), since WAPDEG version 3.09 did not go through the complete verification and validation process required by QAP-SI-0 REV 04 when effective, Post308 is not to be considered qualified and has been designated "to be verified" (TBV-568). Post308 was used within the range of values tested and documented in its Software Routine Report (CRWMS M&O 1998b. *Software Routine Report for WAPDEG (Version 3.09)*, Appendix D).

5.0 Calculation

5.1. Description

Files containing the thermal hydrologic time, temperature, and relative humidity (RH) "histories" at the surface of waste packages in the northeast region of the repository were obtained (DTN:

LL981109004242.064, LL981109104242.065) and are included in the electronic media supporting this calculation (CRWMS M&O 1998i. *Supporting Media for RIP Input Tables From WAPDEG For LA Design Selection: Repository Horizon Elevation - 2-level AML 50% and Near Maximum*) (DTN: MO9906MWDWAP61.001) (it was necessary to replace the designators "lower_data" and "upper_data" with "l" and "u" respectively from each thermal hydrologic file name to satisfy the 40 character Mkhistory maximum file name length requirement). Bin numbers and model identifiers organize these histories with file names like NE_snf_mean_00_noBF_42-2_c_j1_22_05b_upper_data. The nomenclature of this file name reflects the data are for the following: the Northeast (NE) region of the potential repository; spent nuclear fuel (snf) waste packages; the "mean" infiltration rate; the zeroth (00) thermal hydrologic history file bin; no backfill (noBF); long-term average climate conditions (22); and this is a data file (data). The designators "42-2" and "64-2" refer to DF25e and DF25f respectively. The last designators (lower_data and upper_data) refer to the lower and upper tiers (levels) of the proposed design. The designators "c", and "j1" that appear in each file name are not relevant to this calculation. These text files contain columns of ASCII numerical data. Column 1 contains the time (years), Column 2 the waste package surface temperature (°C), Column 3 the relative humidity at the waste package surface (fraction), Column 4 the air mass fraction (Xair), Column 5 the liquid saturation in the invert (fraction), Column 6 the drift wall temperature (°C), and Column 7 the drift wall relative humidity (fraction). In this calculation four WAPDEG runs are made using a total of 47 (DF25e-lower 12 files, DF25e-upper 16 files, DF25f-lower 8 files, and DF25f-upper 11 files) thermal hydrologic history files, each distinguished by differing values of the thermal hydrologic history file bin number and the 42-2 64-2 designators.

These thermal hydrologic history files were processed by the Mkhistory code (after the "lower_data" or "upper_data" designator was removed from each thermal hydrologic history file name). The bulk (but not all) of Mkhistory's processing is devoted to copying Columns 1, 2, and 3 (the columns containing the time, temperature and RH at the waste package surface) from the thermal hydrologic history files named in Column 1 of the Mkhistory input file (NEsfnoBF109e1cj12203b.mk) to the file named in Column 2 of the Mkhistory input file. Note that the first row of ASCII numerical data (corresponding to time equals 0 years) is not copied to the file named in Column 2 of the Mkhistory input file as discussed in the Mkhistory SRR (CRWMS M&O 1998c. *Software Routine Report for Mkhistory (Version 1.00)*). The initial contents of NEsfnoBF422cj12205bl.mk are:

```
12
NE_snf_mean_00_noBF_42-2_c_j1_22_05b_l  NEsf00noBF422cj12205bl.hst
NE_snf_mean_01_noBF_42-2_c_j1_22_05b_l  NEsf01noBF422cj12205bl.hst
NE_snf_mean_02_noBF_42-2_c_j1_22_05b_l  NEsf02noBF422cj12205bl.hst
NE_snf_mean_11_noBF_42-2_c_j1_22_05b_l  NEsf11noBF422cj12205bl.hst
NE_snf_mean_12_noBF_42-2_c_j1_22_05b_l  NEsf12noBF422cj12205bl.hst
NE_snf_mean_21_noBF_42-2_c_j1_22_05b_l  NEsf21noBF422cj12205bl.hst
NE_snf_mean_22_noBF_42-2_c_j1_22_05b_l  NEsf22noBF422cj12205bl.hst
NE_snf_mean_31_noBF_42-2_c_j1_22_05b_l  NEsf31noBF422cj12205bl.hst
NE_snf_mean_32_noBF_42-2_c_j1_22_05b_l  NEsf32noBF422cj12205bl.hst
NE_snf_mean_42_noBF_42-2_c_j1_22_05b_l  NEsf42noBF422cj12205bl.hst
NE_snf_mean_51_noBF_42-2_c_j1_22_05b_l  NEsf51noBF422cj12205bl.hst
NE_snf_mean_52_noBF_42-2_c_j1_22_05b_l  NEsf52noBF422cj12205bl.hst
```

i.e., 12 thermal hydrologic history files are to be processed by Mkhistory and data from NE_snf_mean_00_noBF_42-2_c_j1_22_05b_l is to be copied to NEsf00noBF422cj12205bl.hst, etc. The above are the contents of NEsfnoBF422cj12205bl.mk before execution of Mkhistory (several data segments are appended to this file during Mkhistory program execution as discussed in the Mkhistory SRR (CRWMS M&O 1998c. *Software Routine Report for Mkhistory (Version 1.00)*). The thermal hydrologic history files before and after processing by Mkhistory and the NEsfnoBF109e1cj12203b.mk file after execution of Mkhistory are included in the electronic media supporting this calculation (CRWMS M&O 1998i. *Supporting Media for RIP Input Tables From WAPDEG For LA Design Selection: Repository Horizon Elevation - 2-level AML 50% and Near Maximum*) (DTN: MO9906MWDWAP61.001) (DTN: MO9906MWDWAP61.001).

WAPDEG version 3.09 requires several input files (*.inp, *.cdf, and *.hst files, see below) (DTN: MO9906MWDWAP61.001) and creates several output files (*.aux, *.bin, *.cam, *.crm, *.out, *.pat) (DTN: MO9906MWDWAP61.001). Post308 reads from the *.bin, *.pat, *.out files of the WAPDEG version 3.09 runs and creates several output files (*.asc, *.dat, *.rip) (DTN: MO9906MWDWAP61.001). The *.rip files can be used as input to RIP and are described in Section 6.0.

Analyzing waste package failure histories with the WAPDEG code and creating the associated RIP input tables requires the use of a number of files for the WAPDEG code to read. The following are the files required for WAPDEG:

1) Files containing the relative humidity (RH) and temperature histories at the surface of waste packages (the *.hst files discussed above) (DTN: MO9906MWDWAP61.001).
2) Cumulative distribution function (cdf) for the temperature threshold for the onset of carbon steel corrosion. This threshold is used for the outer barrier or corrosion allowance material (CAM) (file: TThresh.cdf) (CRWMS M&O 1998e. *Cumulative Distribution Functions for the Temperature Threshold for the Onset of Carbon Steel Corrosion*) (DTN: MO9810SPA00013.000).
3) One cdf each for the RH threshold for the onset of humid-air corrosion (file: HARH.cdf) and the transition from humid-air corrosion to aqueous corrosion (file: AQRH.cdf) for the CAM outer barrier (CRWMS M&O 1998f. *Cumulative Distribution Functions for the Relative Humidity Thresholds for the Onset of Carbon Steel Corrosion*) (DTN: MO9810SPA00013.000).
4) Cumulative distribution functions for the CRM general corrosion rates with no drips at 25, 50, and 100°C (files: gnd17550.cdf, gnd27550.cdf, gnd37550.cdf) (CRWMS M&O 1998g. *Cumulative Distribution Functions for No Drip Corrosion Resistant Material General Corrosion Model*) (DTN: MO9810SPA00013.000).
5) Cumulative distribution functions for general corrosion rates under dripping for the inner barrier corrosion resistant material (CRM) at 25, 50, and 100°C (files: g8415050.cdf, g8425050.cdf, g8435050.cdf) (CRWMS M&O 1998h. *Cumulative Distribution Functions for the Dripping Case of the Corrosion Resistant Material General Corrosion Model*) (DTN: MO9810SPA00013.000).
6) The above file names and other model parameters are contained in the WAPDEG input file (*.inp) for the particular simulation being executed. With the exception of the thermal hydrologic

time, temperature, and relative humidity history files discussed in 1) above, the other parameters in the WAPDEG input file are identical to those discussed in the TSPA-VA REV 01 base case calculation (CRWMS M&O 1998d. *Creating Input Tables from WAPDEG for RIP*, Section 5.0) (DTN: MO9810SPA00013.000).

The input files discussed above are used by WAPDEG to produce waste package degradation profiles. The waste package degradation profiles resulting from a WAPDEG simulation are then read by the post processor, Post308, which generates a table in a format appropriate for input into RIP (Golder Associates 1998, pp. 7-22 through 7-25). The RIP input table contains:

1) The fraction of waste packages failed versus time curve for the simulation,
2) The average number of pit penetrations per failed waste package versus time curve and,
3) The average number of patch penetrations per failed waste package versus time curve.

5.1.1. Mkhistory Input Files and Parameters Used

Four Mkhistory input files were used (NEsfnoBF422cj12205bl.mk, NEsfnoBF42-2cj12205bu.mk, NEsfnoBF64-2cj12205bl.mk, and NEsfnoBF64-2cj12205bu.mk). The file names specified in the first column of the Mkhistory input files are read by Mkhistory and the file names specified in the second column contain Mkhistory output. The user-supplied total number of waste packages used was 1 million.

5.1.2. WAPDEG Input Files and Parameters Used

Eight WAPDEG input files were used to generate the RIP input tables for the License Application Design Selection analysis of the two-tier thermal loading repository design: NE1a5s5f25el.inp, NE0a5s6f25el.inp, NE1a5s5f25eu.inp, NE0a5s6f25eu.inp, NE1a5s5f25fl.inp, NE0a5s6f25fl.inp, NE1a5s5f25fu.inp, and NE0a5s6f25fu.inp. These input files are included in the electronic media supporting this calculation (CRWMS M&O 1998i. *Supporting Media for RIP Input Tables From WAPDEG For LA Design Selection: Repository Horizon Elevation - 2-level AML 50% and Near Maximum*) (DTN: MO9906MWDWAP61.001). The first two characters of the input file name indicate that the WAPDEG simulations apply to the northeast (NE) region of the repository. The next character (0 or 1) indicates respectively that a no-drip case is being simulated or that 100% of the waste package surface is subjected to dripping throughout the simulation. The next two characters (a5) indicate that the file is for the base case infiltration. The next two characters (s5 or s6) refer to the different uncertainty/variability split and percentile used of the uncertainty distribution for the median of the CRM general corrosion rate variability distributions (CRWMS M&O 1998g. *Cumulative Distribution Functions for No Drip Corrosion Resistant Material General Corrosion Model*) (DTN: MO9810SPA00013.000). The classifications are as follows:

Uncertainty/Variability Splitting
(0.25 Uncertainty = 0.75 Variability, etc.)

		Uncertainty		
		0.25	0.50	0.75
Percentile	5th	s1	s2	s3
	50th	s4	s5	s6
	95th	s7	s8	s9

From the above table, it is apparent that an input file with s5 designator (e.g. NE1a5**s5**f25el.inp) uses a 50% uncertainty - 50% variability split and use the 50th percentile of the uncertainty distribution for the median of the CRM general corrosion rate variability distributions. An input files with s6 designator (e.g. NE0a5**s6**f25el.inp) uses a 75% uncertainty - 25% variability split and use the 50th percentile of the uncertainty distribution for the median of the CRM general corrosion rate variability distributions. The next five characters in the input file name (the designators f25el, f25eu, f25fl, or f25fu) indicate that these input files pertain to Design Feature 25 of the LADS study (DF25e lower and upper tier and DF25f lower and upper tier, respectively). For reference, below is shown the input file NE1a5s5f25el.inp used in the WAPDEG simulation:

```
NE1a5s5f25el.inp            Bryan Bullard
lower level feature 25e (42-2)
snf, always drip, 100%
Uncertainty/Variability=50/50 drip, 50th Quantile

START OF PARAMETERS
3.09                          |Version number of code
12                            |Number of alternate histories
NEsf00noBF422cj12205bl.hst    |History file 1
     9189, 0., 0.             |packs/history, T std, RH std
NEsf01noBF422cj12205bl.hst    |History file 2
   554025, 0., 0.             |packs/history, T std, RH std
NEsf02noBF422cj12205bl.hst    |History file 3
    45852, 0., 0.             |packs/history, T std, RH std
NEsf11noBF422cj12205bl.hst    |History file 4
    87566, 0., 0.             |packs/history, T std, RH std
NEsf12noBF422cj12205bl.hst    |History file 5
   140720, 0., 0.             |packs/history, T std, RH std
NEsf21noBF422cj12205bl.hst    |History file 6
    13424, 0., 0.             |packs/history, T std, RH std
NEsf22noBF422cj12205bl.hst    |History file 7
    79685, 0., 0.             |packs/history, T std, RH std
NEsf31noBF422cj12205bl.hst    |History file 8
     5562, 0., 0.             |packs/history, T std, RH std
NEsf32noBF422cj12205bl.hst    |History file 9
    46451, 0., 0.             |packs/history, T std, RH std
NEsf42noBF422cj12205bl.hst    |History file10
    12212, 0., 0.             |packs/history, T std, RH std
NEsf51noBF422cj12205bl.hst    |History file11
     1814, 0., 0.             |packs/history, T std, RH std
NEsf52noBF422cj12205bl.hst    |History file12
     3506, 0., 0.             |packs/history, T std, RH std
10.0, 2.0                     |Thickness of outer, inner barriers (cm)
75., 0.35                     |% thick to fail CRM, frac variance to packs
400, 964, 3100, 3100          |Number of packs, patches/pack, pits/patch
```

1.0, 1.e6, 1200	Bin start time & end time (y), and # of bins
1.e4, 5.e4, 1.e5, 1.e6	Output times (y) for cumul. pit penetrations
304058394, F, F	Random# seed, restart flag, ignore CAM variance
0.0, 0.0	Max temp, RH change over a time step (C, %RH)
180., 180.	Angle defining top/bottom (degrees)
Fixed	Distribution for fraction top seeing drips
1.	Distribution parameter(s)
Fixed	Distribution for fraction bottom seeing drips
1.	Distribution parameter(s)
Fixed	Distribution for dripping start time
0.	Distribution parameter(s)
Fixed	Distribution for dripping stop time
1000000.	Distribution parameter(s)
T, F	Neutral(T/F) water initially, new water (T/F)
Fixed	Distr for time range for ceramic protection
0.0	Distribution parameter(s)
1.0	Package variance share
[No Drip Model, CAM]	This segment always required
CAMGeneral+PitMultiples	CAM corrosion model for no drips
B-Normal	Distribution for pit multiple
1.5, 0.25, 1.0, 1.0e6	Mean, StDev, Min, Max
[No Drip Model, CRM]	This segment always required
CRMGeneralRateOnly	CRM corrosion model for drips
3, 1.e+6	Number of dists (temps), max CRM rate
25.	Temp appropriate for dist #1
File	Distribution type for #1
gnd17550.cdf	Distribution parameter (s)
50.	Temp appropriate for dist #1
File	Distribution type for #1
gnd27550.cdf	Distribution parameter (s)
100.	Temp appropriate for dist #2
File	Distribution type for #2
gnd37550.cdf	Distribution parameter (s)
[No Drip Features]	This segment always required
File	Distr for thermal protection temperature
TThresh.cdf	Distribution parameter(s)
File	Dist type for humid-air initiation
HARH.cdf	Distribution parameter(s)
File	Dist type for humid-air/aqueous transition
AQRH.cdf	Distribution parameter(s)
1.0	RH correlation factor
0.0, 0.0	Galvanic protect depth %, % patches protected
0.0	Spalling depth as a % of thickness
Fixed	Dist for multiple for CAM corrosion rate
1.0	Distribution parameter(s)
Fixed	Dist for multiple for CRM corrosion rate
1.0	Distribution parameter(s)
1.0	Pack variance share for multiples
[Neutral Drip Model, CAM]	Required if any non-neutral drips can be seen
CAMGeneral+PitMultiples	CAM corrosion model for no drips
B-Normal	Distribution for pit multiple
1.5, 0.25, 1.0, 1.0e6	Mean, StDev, Min, Max
[Neutral Drip Model, CRM]	Required if any non-neutral drips can be seen
CRMGenrate+ArrheniusPit	CRM corrosion model for drips
3, 1.e+6	Number of dists (temps), max CRM rate
25.	Temp appropriate for dist #1
File	Distribution type for #1
g8415050.cdf	Distribution parameter (s)
50.	Temp appropriate for dist #1

```
File                          | Distribution type for #1
g8425050.cdf                  | Distribution parameter (s)
100.                          | Temp appropriate for dist #2
File                          | Distribution type for #2
g8435050.cdf                  | Distribution parameter (s)
Normal                        | Distribution type for A (b0)
11.275, 2.4495                | Distribution parameter(s)
Fixed                         | Distribution type for K (b1)
5.5494e+003                   | Distribution parameter(s)
Fixed                         | Distribution type for n
0.5                           | Distribution parameter(s)
[Neutral Drip Features]       | Required if any non-neutral drips can be seen
File                          | Distr for thermal protection temperature
TThresh.cdf                   | Distribution parameter(s)
Uniform                       | Dist type for CRM LC T init
80., 100.                     | Distribution parameter
File                          | Dist type for humid-air initiation
HARH.cdf                      | Distribution parameter(s)
File                          | Dist type for humid-air/aqueous transition
AQRH.cdf                      | Distribution parameter(s)
1.0                           | RH correlation factor
0.0, 0.0                      | Galvanic protect depth %, % patches protected
0.0                           | Spalling depth as a % of thickness
Fixed                         | Dist for multiple for CAM corrosion rate
1.0                           | Distribution parameter(s)
Fixed                         | Dist for multiple for CRM corrosion rate
1.0                           | Distribution parameter(s)
1.0                           | Pack variance share for multiples
```

One should note that the "number of packs" on the fourth input file line after the last history file name is 400 for both input files and that the sum of the "packs/history" (the first value on each line after the history file name) differs from this value (since Mkhistory was executed with a user-supplied 1 million total number of waste packages). In the case where the "number of packs" differs with the sum of the "packs/history," WAPDEG normalizes the "packs/history" to the "number of packs" based on the fraction of the sum of the entered "packs/history" for all histories used (i.e., the "packs/history" are normalized so that they sum to 400 (the "number of packs")).

To gain a deeper understanding of the WAPDEG code, refer to the Software Routine Report for WAPDEG (CRWMS M&O 1998b. *Software Routine Report for WAPDEG (Version 3.09)*).

5.2. Procedure

Mkhistory was executed in a Windows NT 4.0 MS-DOS prompt window. Mkhistory prompts the user for a list-file name (i.e., NEsfnoBF422cj12205bl.mk). The Mkhistory program then prompts the user for the total number of waste packages to be considered. The user entered "1000000".

WAPDEG was executed in a Windows NT 4.0 MS-DOS prompt window. WAPDEG prompts the user for the WAPDEG input file name, e.g., NE1a5s5f25el.inp.

The "raw" output from a WAPDEG simulation consists of six files: a *.out file, *.pat file, *.bin file, *.crm file, *.cam file, and *.aux file (where "*" is the input file name prefix). The content and format of these files are discussed in the WAPDEG version 3.09 Software Routine Report (CRWMS M&O

1998b, Section 4.1). These files are also included in the electronic media supporting this calculation (CRWMS M&O 1998i. *Supporting Media for RIP Input Tables From WAPDEG For LA Design Selection: Repository Horizon Elevation - 2-level AML 50% and Near Maximum*) (DTN: MO9906MWDWAP61.001). Only the *.out (waste package failure curves), *.pat (cumulative number of patch penetrations for each waste package), and *.bin (cumulative number of pit penetrations for each waste package) files are used by Post308 to create the RIP input tables.

In order to create the tables for input to RIP, Post308 is executed in a Windows NT 4.0 MS-DOS prompt window within the same directory as the output files from WAPDEG (i.e., *.bin, *.pat, *.out). The program prompts the user for the particular filename prefix that is common to the WAPDEG simulation output files to be post processed. After the program post processes the WAPDEG output, it prompts the user to enter a file name for the RIP input table to be created. The RIP input tables were chosen to have the same prefix name as the corresponding WAPDEG input files with a *.rip extension. The output from the post processor consists of three files; *.asc, *.dat, and *.rip. The content and format of these files are discussed in the WAPDEG version 3.09 Software Routine Report (CRWMS M&O 1998b, Appendix D). These files are also included in the electronic media supporting this calculation (CRWMS M&O 1998i. *Supporting Media for RIP Input Tables From WAPDEG For LA Design Selection: Repository Horizon Elevation - 2-level AML 50% and Near Maximum*) (DTN: MO9906MWDWAP61.001).

6.0 Results

Since unqualified inputs were used in the development of the results presented in this section, they should be considered TBV. This document will not directly support any construction, fabrication, or procurement activity, and therefore, the inputs and outputs are not required to be procedurally controlled as TBV. However, any use of the data from this analysis for inputs into documents supporting construction, fabrication, or procurement is required to be controlled as TBV in accordance with appropriate procedures. Furthermore, this calculation makes use of software (WAPDEG version 3.09 and Post308) that are unqualified (TBV-568).

All input and output files relevant to this calculation are included in the electronic media supporting this calculation (CRWMS M&O 1998i. *Supporting Media for RIP Input Tables From WAPDEG For LA Design Selection: Repository Horizon Elevation - 2-level AML 50% and Near Maximum*) (DTN: MO9906MWDWAP61.001). For brevity, only selected files are reproduced in hardcopy form within this section.

The primary outputs of Mkhistory are the *.hst files used as input to WAPDEG. For reference the contents of NEsf00noBF42-2cj12205bu.hst are:

```
1.0       188.49    0.276860
1.5       192.41    0.191170
2.0       196.92    0.097986
2.5       201.24    0.069563
3.0       205.03    0.056890
3.5       207.99    0.051216
4.0       210.71    0.048993
4.5       212.14    0.050194
```

5.0	212.63	0.050974
6.0	212.22	0.052132
7.0	210.37	0.052903
8.0	208.39	0.053664
9.0	205.34	0.054090
10.0	202.04	0.055508
11.0	199.37	0.057703
12.0	196.54	0.061925
13.0	193.57	0.066417
15.0	186.92	0.077144
20.0	172.65	0.107240
25.0	159.34	0.160150
30.0	147.38	0.231250
35.0	137.78	0.329230
40.0	128.73	0.462390
45.0	122.86	0.519180
50.0	118.50	0.556170
51.0	117.99	0.558960
55.0	115.90	0.570380
60.0	113.31	0.583080
70.0	107.44	0.603380
80.0	102.52	0.621860
90.0	99.52	0.640370
100.0	94.29	0.652360
101.0	94.11	0.653230
105.0	93.24	0.657600
110.0	92.15	0.662420
120.0	90.33	0.673620
150.0	84.39	0.709050
180.0	81.39	0.729130
200.0	79.59	0.743540
220.0	78.39	0.752680
230.0	77.82	0.757130
260.0	76.39	0.771000
300.0	74.92	0.785730
350.0	73.59	0.800700
400.0	72.45	0.813330
450.0	71.45	0.823270
500.0	70.51	0.833190
550.0	69.63	0.841810
600.0	68.80	0.849190
700.0	67.30	0.862510
800.0	66.10	0.873010
900.0	65.00	0.883580
1000.0	63.97	0.890580
1100.0	63.14	0.896260
1200.0	62.32	0.901730
1300.0	61.53	0.907220
1400.0	60.69	0.912940
1500.0	59.84	0.918930
1600.0	59.24	0.921840
1800.0	58.06	0.926790
2000.0	56.91	0.933140
2500.0	54.74	0.940280
3000.0	53.16	0.944620
4000.0	50.94	0.948970
5000.0	49.37	0.950470
6000.0	47.97	0.951690
8000.0	45.49	0.957480

10000.0	43.48	0.959160
15000.0	38.82	0.966910
20000.0	35.32	0.970250
30000.0	30.22	0.978590
40000.0	27.33	0.982420
50000.0	25.70	0.985740
60000.0	24.57	0.988610
80000.0	23.20	0.990970
100000.0	22.41	0.993100
120000.0	22.04	0.993840
150000.0	21.62	0.995060
200000.0	21.24	0.996020
300000.0	20.94	0.997080
400000.0	20.82	0.997470
500000.0	20.75	0.997690
600000.0	20.71	0.997820
700000.0	20.68	0.997920
800000.0	20.66	0.997980
900000.0	20.65	0.998040

The other outputs of Mkhistory are appended to the *.mk files and consist of the history file input segment (i.e., all the text in the input file lines from "12 |Number of alternate histories" to "8548, 0., 0. |packs/history, T std, RH std"), documentation of the sum of the fraction and total number of waste packages represented by each history, and a text segment that could be used to graph all of the histories processed. These files are contained in the electronic media supporting this calculation (CRWMS M&O 1998i. *Supporting Media for RIP Input Tables From WAPDEG For LA Design Selection: Repository Horizon Elevation - 2-level AML 50% and Near Maximum*) (DTN: MO9906MWDWAP61.001).

The primary outputs of the Post308 post processor are the RIP input tables. The RIP input tables are formatted as multidimensional lookup-tables as discussed in the RIP - Theory Manual and User's Guide (Golder Associates 1998, pp. 7-22 through 7-25).

For reference the RIP input table NE1a5s5f25fu.rip (DTN: MO9906MWDWAP61.001) is shown below.

```
! From wapdeg file: NE1a5s5f25fu
! From wapdeg version: 3.09
! Postprocessor: post308
! NE1a5s5f25fu.inp           Bryan Bullard
! upper level feature 25f (64-2)
! snf, always drip, 100%
! Uncertainty/Variability=50/50 drip, 50th Quantile
!
! START OF PARAMETERS
 2
 3  83
 1   2   3
          0.0000
       2599.1596
       3539.6796
       7983.4521
      15226.7235
      19859.4680
```

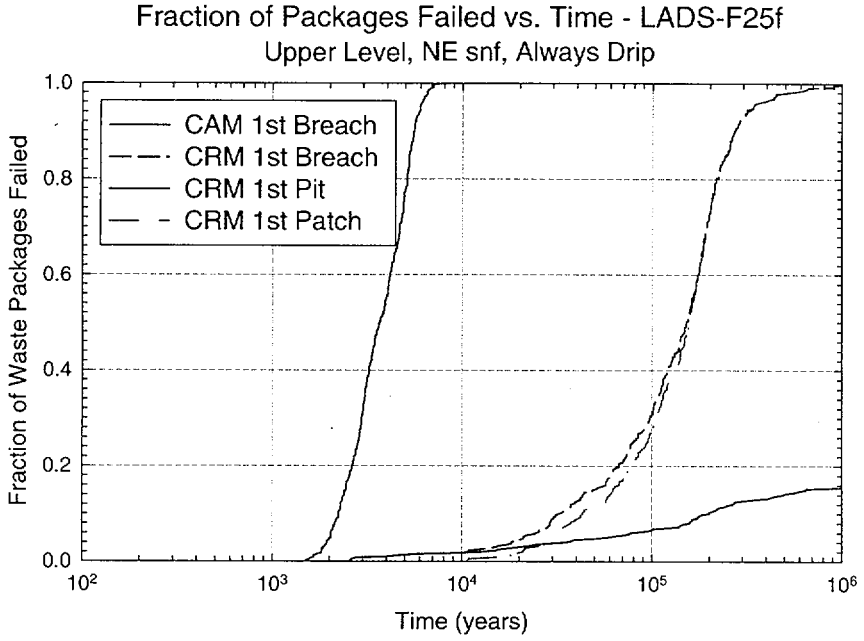
23610.8407
27399.1713
29513.3962
31269.0814
34696.6691
38469.3743
41697.9902
46268.7519
53769.6409
59225.2899
61667.6733
65702.8101
69993.4762
73711.6236
76739.5394
78978.1935
82714.9373
88116.5658
93337.8006
97164.4050
100004.4183
102921.7579
105319.1137
108397.4805
112206.8028
114815.3621
116817.3084
120231.7554
124456.9598
128087.6316
131831.4983
137257.4661
142071.5752
144543.9771
147917.3740
152232.4355
155778.3845
158489.3192
161252.7744
164058.9773
166919.5463
169824.3652
171790.8387
174786.2221
177827.9410
179887.0915
181970.0859
184077.2001
186208.7137
188364.9089
190546.0718
193868.4756
197242.2736
200681.4339
204173.7945
206538.0156
208929.6131
211348.9040
213796.2090

217524.0074		
222590.7924		
227775.5980		
233081.1733		
239893.8907		
249767.5290		
257039.5783		
261521.3778		
267612.9932		
277035.8528		
288415.8928		
302035.2022		
316241.7379		
338993.8854		
398899.1624		
508470.4061		
739642.8510		
1000000.0000		
0.0000	0.0000	0.0000
0.0000	0.0000	0.0000
0.0090	11.3721	0.0000
0.0170	30.1320	0.0340
0.0305	20.1224	0.2386
0.0451	13.8571	0.5799
0.0579	10.9653	0.8724
0.0688	9.3690	1.1939
0.0840	7.7410	1.2314
0.0952	6.8354	1.2822
0.1062	6.1964	1.4141
0.1200	5.6528	1.5173
0.1305	5.3723	1.6407
0.1458	6.2268	1.7494
0.1565	4.6715	1.9914
0.1741	4.3154	2.1396
0.1833	4.1353	2.2176
0.1968	3.9587	2.2878
0.2081	3.8783	2.5055
0.2213	3.7264	2.6292
0.2340	3.6102	2.6968
0.2479	3.5301	2.7585
0.2564	4.4700	2.9043
0.2712	3.3728	3.2576
0.2823	3.7058	3.7430
0.2962	3.4895	4.0339
0.3081	7.3494	4.2133
0.3264	3.7906	4.3853
0.3356	3.1110	4.5173
0.3441	2.7750	4.7622
0.3608	2.8362	4.9701
0.3771	2.8775	5.0787
0.3853	3.0912	5.1902
0.3973	3.5290	5.4334
0.4096	3.6368	5.7526
0.4219	5.0853	5.9640
0.4314	3.1439	6.3314
0.4414	3.8009	6.8735
0.4649	2.3444	7.0980
0.4736	2.4284	7.3275
0.4816	4.5798	7.6525

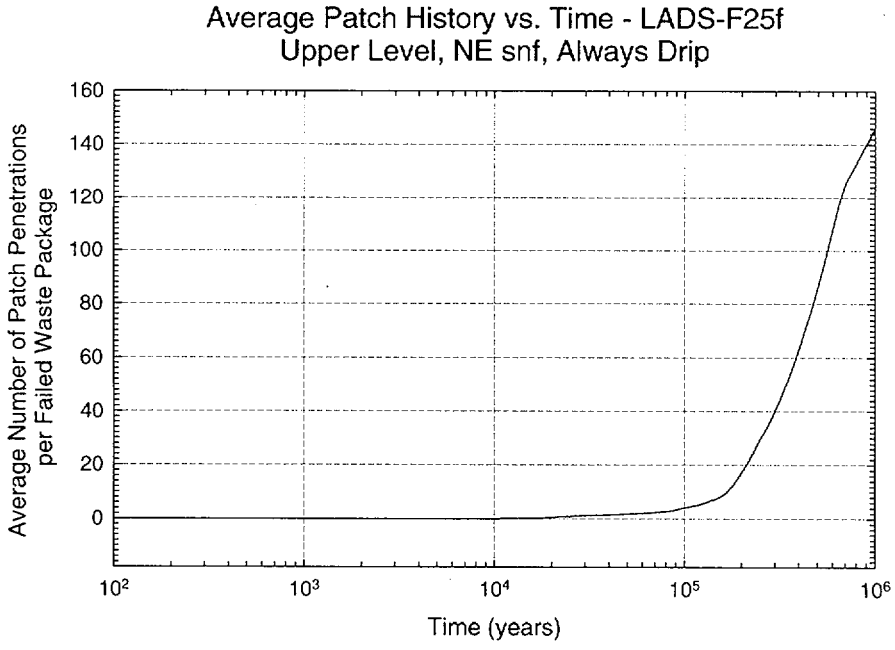
0.4976	2.8469	8.1234
0.5106	3.7735	8.5289
0.5279	2.6425	8.7989
0.5398	3.1991	9.1623
0.5532	3.4348	9.5180
0.5616	3.5807	10.0515
0.5739	3.4019	10.6501
0.5856	2.1090	10.9248
0.5966	2.2162	11.5970
0.6158	2.3994	12.0620
0.6285	2.7886	12.4790
0.6446	7.6364	12.9381
0.6480	2.6504	13.6144
0.6627	2.5274	14.0854
0.6773	2.9602	14.5168
0.6860	4.3297	15.0958
0.7027	4.6223	15.8743
0.7138	2.8125	16.7524
0.7279	3.5084	17.5775
0.7467	3.0000	18.3011
0.7594	3.3710	18.7380
0.7648	2.0627	19.4865
0.7716	2.4204	20.1280
0.7863	2.6071	20.5196
0.7982	2.6707	21.5147
0.8065	2.9296	22.9963
0.8232	2.2860	24.1348
0.8343	2.8123	25.4746
0.8439	2.4103	27.2630
0.8560	3.2069	29.6507
0.8713	3.6985	31.1631
0.8838	3.2760	31.9583
0.8941	2.6398	33.2048
0.9058	2.6107	35.2567
0.9191	3.7762	37.7705
0.9290	3.8395	40.9808
0.9424	3.1976	44.0128
0.9508	3.2300	49.3158
0.9637	4.2460	63.1025
0.9797	4.0978	87.5799
0.9898	3.5086	126.0925
0.9950	2.8970	145.4950

The RIP input table consists of a column of times in years (the first single column of data) followed by three columns consisting of the fraction of waste packages failed, the number of pit penetrations per failed waste package, and the number of patch penetrations per failed waste package. These last three columns all share the same time grid (the first single column of data).

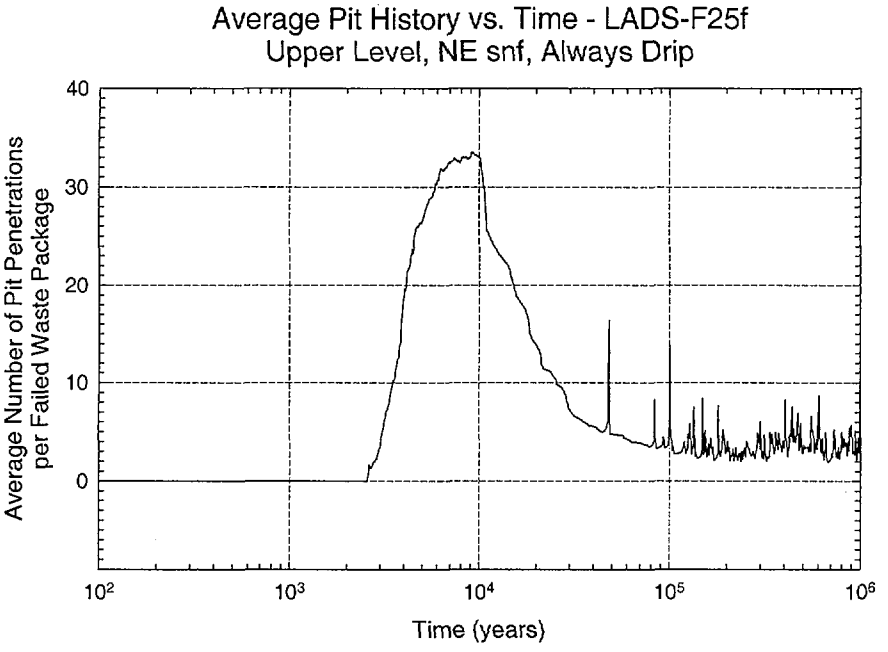
Presented below is a graph (derived from the NE1a5s5f25fu.dat file) of the first breach (either by patch or pit penetration) curves of both the CAM (outer carbon steel) and CRM (inner Alloy 22) barriers, and the first patch and first pit penetration curves of the CRM inner barrier for the DF25f upper tier dripping (NE1a5s5f25fu.inp) case:



Below is shown a graph of the average number of patch penetrations per failed waste package (derived from the NE1a5s5f25fu.asc file):



Presented below is a graph of the average number of pit penetrations per failed waste package (also derived from the NE1a5s5f25fu.asc file):



The first breach curve for the CRM, the average number of patch penetrations per failed waste package curve, and the average number pit penetrations per failed waste package curve are also represented in the RIP input table, NE1a5s5f25fu.rip.

7.0 References

CRWMS M&O 1998a. *Total System Performance Assessment-Viability Assessment (TSPA-VA) Analyses Technical Basis Document - Chapter 5, Waste Package Degradation Modeling And Abstraction.* B00000000-01717-4301-00005 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19981008.0005. DTN: MO9807MWDWAPDG.000.

CRWMS M&O 1998b. *Software Routine Report for WAPDEG (Version 3.09).* CSCI: 30048 V3.09. DI: 30048-2999 REV 02. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19981012.0224.

CRWMS M&O 1998c. *Software Routine Report for Mkhistory (Version 1.00).* CSCI: 30080 V1.00. DI: 30080-2999 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19981202.0194.

CRWMS M&O 1998d. *Creating Input Tables from WAPDEG for RIP.* B00000000-01717-0210-00013 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19981110.0431. DTN: MO9810SPA00013.000.

CRWMS M&O 1998e. *Cumulative Distribution Functions for the Temperature Threshold for the Onset of Carbon Steel Corrosion.* B00000000-01717-0210-00015 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980603.0253. DTN: MO9810SPA00013.000.

CRWMS M&O 1998f. *Cumulative Distribution Functions for the Relative Humidity Thresholds for the Onset of Carbon Steel Corrosion.* B00000000-01717-0210-00016 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980603.0257. DTN: MO9810SPA00013.000.

CRWMS M&O 1998g. *Cumulative Distribution Functions for No Drip Corrosion Resistant Material General Corrosion Model.* B00000000-01717-0210-00012 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980715.0174. DTN: MO9810SPA00013.000.

CRWMS M&O 1998h. *Cumulative Distribution Functions for the Dripping Case of the Corrosion Resistant Material General Corrosion Model.* B00000000-01717-0210-00014 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980831.0012. DTN: MO9810SPA00013.000.

CRWMS M&O 1998i. *Supporting Media for RIP Input Tables From WAPDEG For LA Design Selection: Repository Horizon Elevation - 2-level AML 50% and Near Maximum.* Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990615.0040. DTN: MO9906MWDWAP61.001.

CRWMS M&O 1998j. *Software Routine Report for WAPDEG (Version 3.07).* CSCI: 30048 V3.07. DI: 30048-2999 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980715.0166.

Golder Associates 1998. *RIP Integrated Probabilistic Simulator for Environmental Systems, Theory Manual and User's Guide.* Redmond, Washington: Golder Associates Inc. TIC: 238560.

8.0 Attachments

N/A.